Mad Roaring Mills Project

Hydrology Report

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for:
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Introduction

The Mad Roaring Mills Project includes treatments to improve watershed condition and function including non-commercial thinning, hand-piling of material, prescribed burning, road treatments including decommissioning, closure, culvert removals or replacements, road relocation, and stream restoration in the Lower Mad River, Roaring Creek, and Mills Creek - Entiat sub-watersheds,

This report discusses the affected environment, existing condition, and the environmental consequences of the Mad Roaring Mills Project on water quality, riparian function, channel morphology, and watershed condition. Water quality, riparian function, channel morphology, and watershed condition reflect the integrated effect of climate, geology, physiography, and land use (Beschta and Platts, 1986; Naiman and Bilby, 1998). Existing condition and affected environment in this report are evaluated in terms of how climate, geology, and physiography affect hydrologic processes. This report examines how past and present disturbance interacts with these controls to affect hydrologic function, the condition of streams, rivers, and other water resources, and how the Mad Roaring Mills Project would improve hydrologic processes and watershed condition.

This report addresses the following needs for action:

- Maintain and Improve Forest Vegetation.
    a. There is a need to maintain low hazardous fuels conditions to reduce the threat of future uncharacteristic wildfire to the adjacent private landowners, support fire as a natural process, and provide for long-term firefighter and public safety.
    b. There is a need to thin young stands to accelerate tree growth to promote mature forest on the landscape.
    c. There is a need to reduce fuels in and around mature forested stands to maintain existing forest structure on the landscape.

- Maintain and Improve Aquatic Habitat
    a. There is a need to improve stream habitat, such as creating side channels and placing large woody material in the Mad River and Roaring Creek drainages to restore floodplain connection and improve aquatic habitat for listed fish species.
    b. There is a need to remove barriers located in streams to allow aquatic organisms to move freely.
    c. There is a need to reduce road density on the landscape to reduce impacts to aquatic resources.

- Improve the Transportation Network.
    a. There is a need to provide a transportation system that is affordable, safe, and efficient for administration, public use and protection of National Forest System lands while also providing high quality recreation experiences, resource protection and access for forest management.

Protection and improvement of hydrologic function is a driver of the Mad Roaring Mills Project the purpose of which is to:

- Improve stream and riparian habitat for Threatened and Endangered fish species, including steelhead, bull trout and spring chinook.
- Allow aquatic organism access to more stream habitat.
- Reduce sediment input to streams from roads.
- Establish a sustainable road network.

Resource Indicators and Measures

The resource elements, indicators, and measures used to analyze and compare potential effects of the Mad Roaring Mills project on hydrologic resources are shown in Table 1. Indicators and measures address the purpose and need and key internal issues raised during project planning. A description of how each measure was calculated is included in the Methodology section of this report.

Table 1: Resource indicators and measures for measuring and comparing potential effects between alternatives.

Resource Element	Resource Indicators	Measures
Water Quality	Potential erosion, sedimentation, and flow alteration from the road system	• Road density • Miles of hydrologically connected roads • Riparian road density • Miles of road within areas with high erosion potential • Number of road-stream crossings
	Upland vegetation conditions with the potential to affect water quality	• Acres where fire risk is reduced
Riparian Function and Channel Morphology	Riparian and upland conditions with the potential to affect riparian function and channel morphology	• Acres of floodplain and wetland condition restored • Miles of road within riparian reserves • Miles of stream channel restored

Methodology

Scale of Analysis and Watershed Hierarchy

The 70,000-acre Mad Roaring Mills project includes the Lower Mad River (170200100103), Mills Creek – Entiat River (170200100209) and the Roaring Creek (170200100208) sub-watersheds in the Upper Columbia-Entiat subbasin. The watershed hierarchy of the Mad Roaring Mills project is shown in Table 2.

Table 2: Watershed hierarchy of the Mad Roaring Mills project.

Basin	Subbasin	Watershed	Sub-watershed
Upper Columbia 170200	Upper Columbia-Entiat 17020010	Mad River 1702001001	Lower Mad River 170200100103
		Entiat River 1702001002	Mills Creek – Entiat River 170200100209 Roaring Creek 170200100208

The hydrologic analysis area for the Mad Roaring Mills Project are the three sub-watersheds mentioned above. Direct and indirect effects are analyzed at the scale of all National Forest System Lands in the respective sub-watersheds. Cumulative effects are analyzed for all lands within the project area. The temporal scale for effects analysis is 30 years--the time it is estimated to take for morphological improvements in stream channel variables from upland treatments to be measurable.
Sub-watersheds, and streams in the project area are shown in Figure 1.

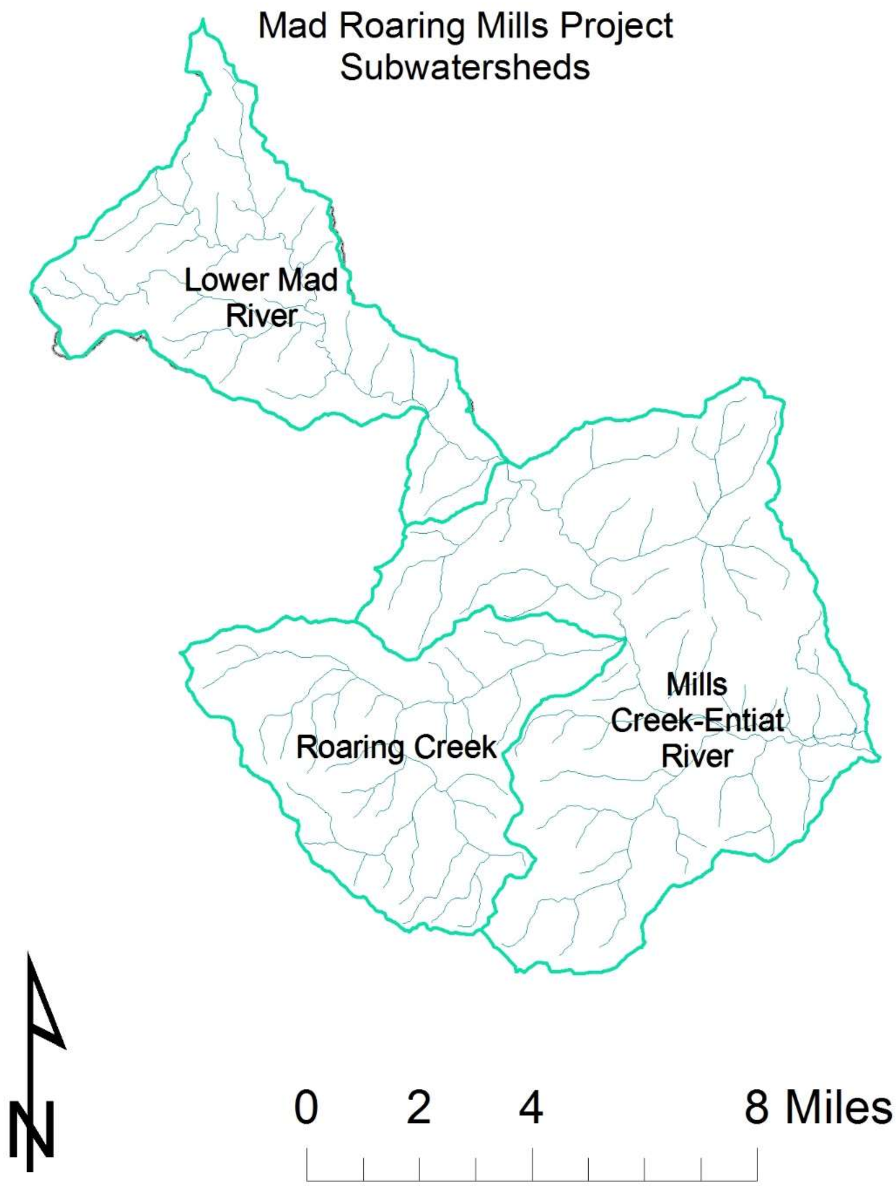

Figure 1: Sub-watersheds in the Mad Roaring Mills Project.

Development of Restoration Treatments

Restoration treatments for the Mad Roaring Mills project were developed and prioritized at the sub-watershed scale using the Okanogan-Wenatchee Restoration Strategy Procedures (USDA 2015). This procedure incorporates geomorphic and ecological principles found in existing watershed and aquatic resource restoration planning mechanisms at varying spatial scales (i.e. Robinson et al 2010 and Rosgen 2006). This procedure targets and measures the degree of impact or impairment roads pose to watershed and aquatic resources and focuses restoration efforts on roads that cause the greatest resource damage. The roads section of the Existing Condition section of this report describes the potential effects of the road system on hydrologic and aquatic function.

The goal of this analysis procedure is to compare how existing conditions have departed from historic pre-European settlement conditions and identify the variables that are influencing the departure from historic conditions. The steps used to determine degree of impairment from the road system at the sub-watershed scale are outlined below.

Physical variables including road density, increase in drainage network from the road system, percentage of the road network in riparian reserves, number of road crossings per stream mile and intrinsic landscape erosion potential were rated for each sub-watershed (Table 3). A final rating for each catchment was calculated and assigned a color value based on function and degree of departure from historic conditions using the following system:

- Red: Not functional, high degree of departure
- Yellow: Functioning at risk, moderate degree of departure
- Green: Functioning, low degree of departure

Table 3: Ranking and relative weight criteria of physical variables affecting watershed at the sub-watershed scale for the Mad Roaring Mills project.

Metric	Sub-Watershed Ranking Criteria	Sub-Watershed Condition	Sub-Watershed Assignment
Road density	0-1 mi/mi^2	Functioning	Green
	1-2.4 mi/mi^2	Functioning at risk	Yellow
	>2.4 mi^2	Not Functional	Red
Riparian road density	0-1 mi/mi^2	Functioning	Green
	1-2.4 mi/mi^2	Functioning at risk	Yellow
	>2.4 mi^2	Not Functional	Red
Increase in drainage network from the road system	0-10 %	Functioning	Green
	10-30 %	Functioning at risk	Yellow
	>30 %	Not Functional	Red
Percent riparian area road length to stream length (calculated as length of road in riparian area (100m) divided by stream length)	0-30 %	Functioning	Green
	30-99 %	Functioning at risk	Yellow
	>100 %	Not Functional	Red

Road crossings per stream mile	0-1	Functioning	Green
	1-3	Functioning at risk	Yellow
	>3	Not Functional	Red
Intrinsic sediment delivery potential- using landtype association classification process—see description	Low	Functioning	Green
	Moderate	Functioning at risk	Yellow
	High	Not Functional	Red

Quantification of Physical Variables

Road density was calculated at the sub-watershed scale using miles of open and closed (maintenance level 1-5) National Forest System Road (NFS) divided by square miles of land within each sub-watershed. Road density was ranked by sub-watershed using the criteria in Table 3. Road density provides a coarse metric to gage potential impacts to hydrologic function and aquatic and riparian ecosystems and therefore received a relatively low weight in this analysis. Existing road densities across the Mad Roaring Mills project sub-watersheds are shown in Figure 2. Road density is within the “not functional” category across all catchments.

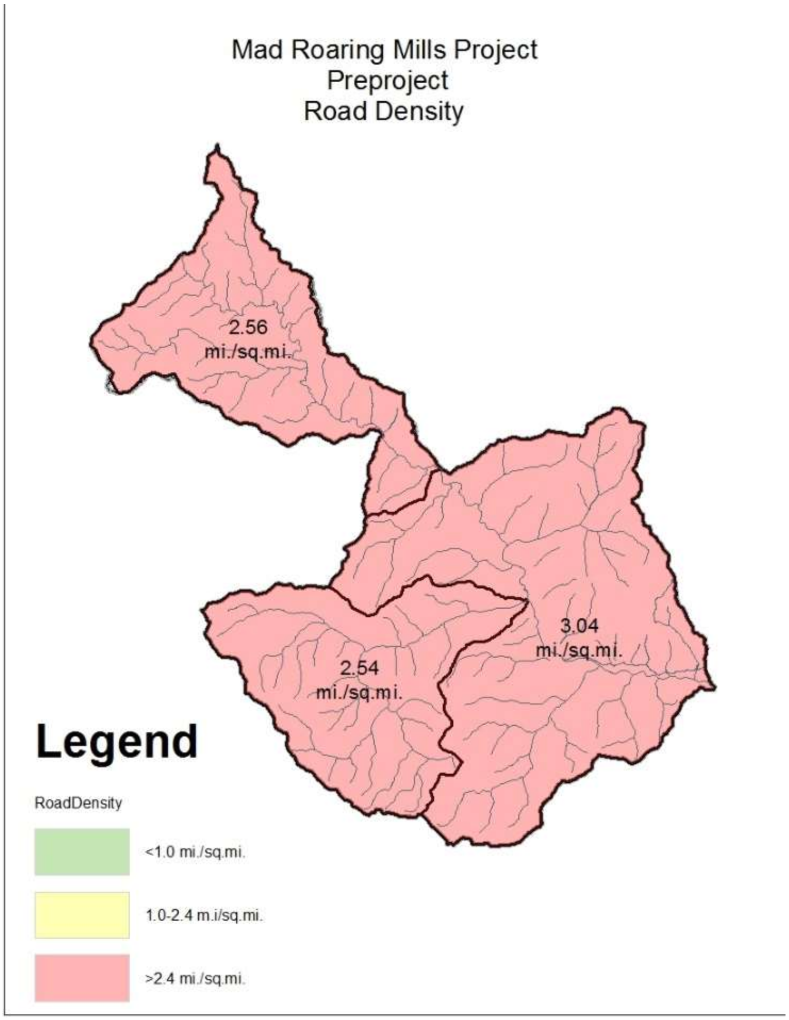

Figure 2: Road density across the Mad Roaring Mills project sub-watersheds. Road density within each catchment was within the "not functional" category.

Riparian road density was calculated at the sub-watershed scale using miles of open and closed (maintenance level 1-5) National Forest System Road (NFS) divided by square miles of land within riparian reserve for each sub-watershed. Riparian road density was ranked by sub-watershed using the criteria in Table 3. Riparian road density provides a coarse, yet more aquatic focused, metric than road density to gage potential impacts to hydrologic function and aquatic and riparian ecosystems. Riparian Road Densities within the project area are shown in Figure 3.

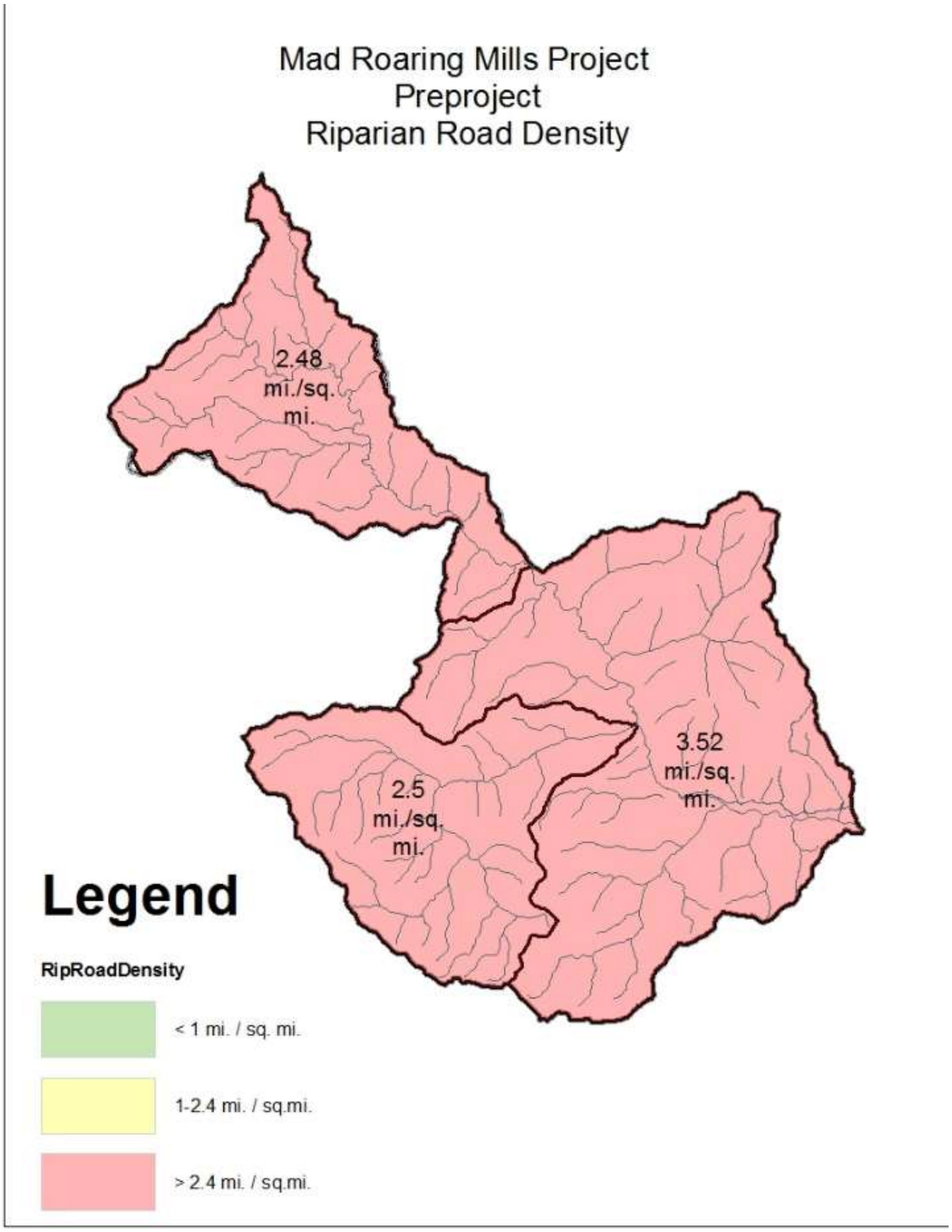

Figure 3: Riparian road densities within the Mad Roaring Mills project area

Increase in drainage network from the road system was calculated using miles of road that are hydrologically connected to the stream network based on road position, analysis of slope and potential connectivity to the stream system. Increase in drainage network from the road system classified for catchments across the Mad Roaring Mills project sub-watersheds is shown in Figure 4. The Mills Creek – Entiat River sub-watershed is rated as “not functional” for this metric, while the Lower Mad River and Roaring Creek sub-watersheds are rated as “functioning at risk”. Ratings for the sub-watersheds indicate that hydrologically connected roads are one of the primary drivers of impaired function within the project sub-watersheds.

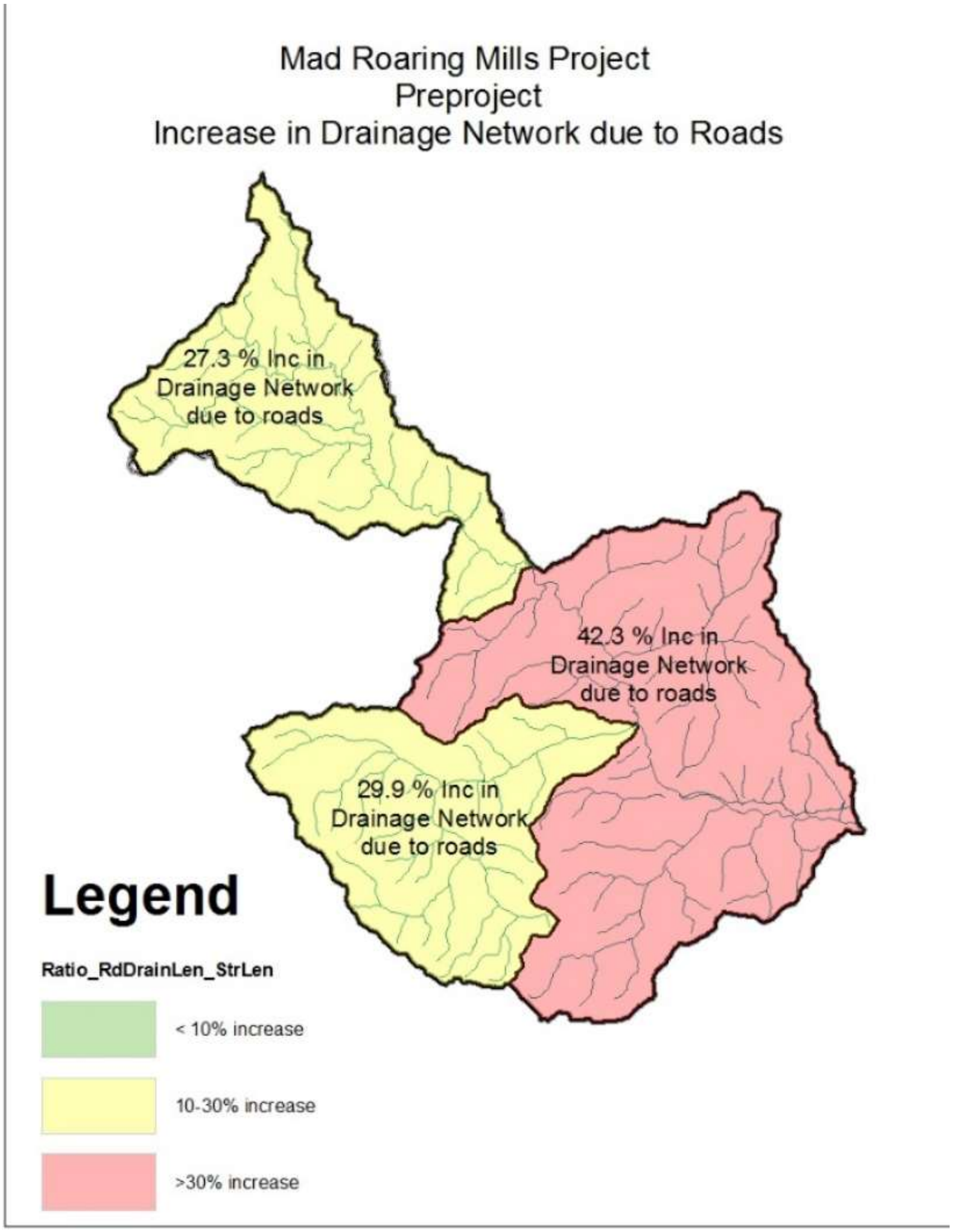

Figure 4: Increase in drainage network from the road system across Mad Roaring Mills project sub-watersheds.

Ratio of road network within riparian reserves to stream length was calculated as length of road in riparian reserves divided by total stream length. Similar to the increase in drainage network from the road system metric, this metric is a measure of the potential for the road system to impact the stream network and riparian habitat. The ratio of the road network within riparian reserves to stream length classified for sub-watersheds within the project are shown in Figure 5. Mills Creek – Entiat River is rated as "non-functioning" while Lower Mad River and Roaring Creek sub-watersheds are rated as "functioning at risk".

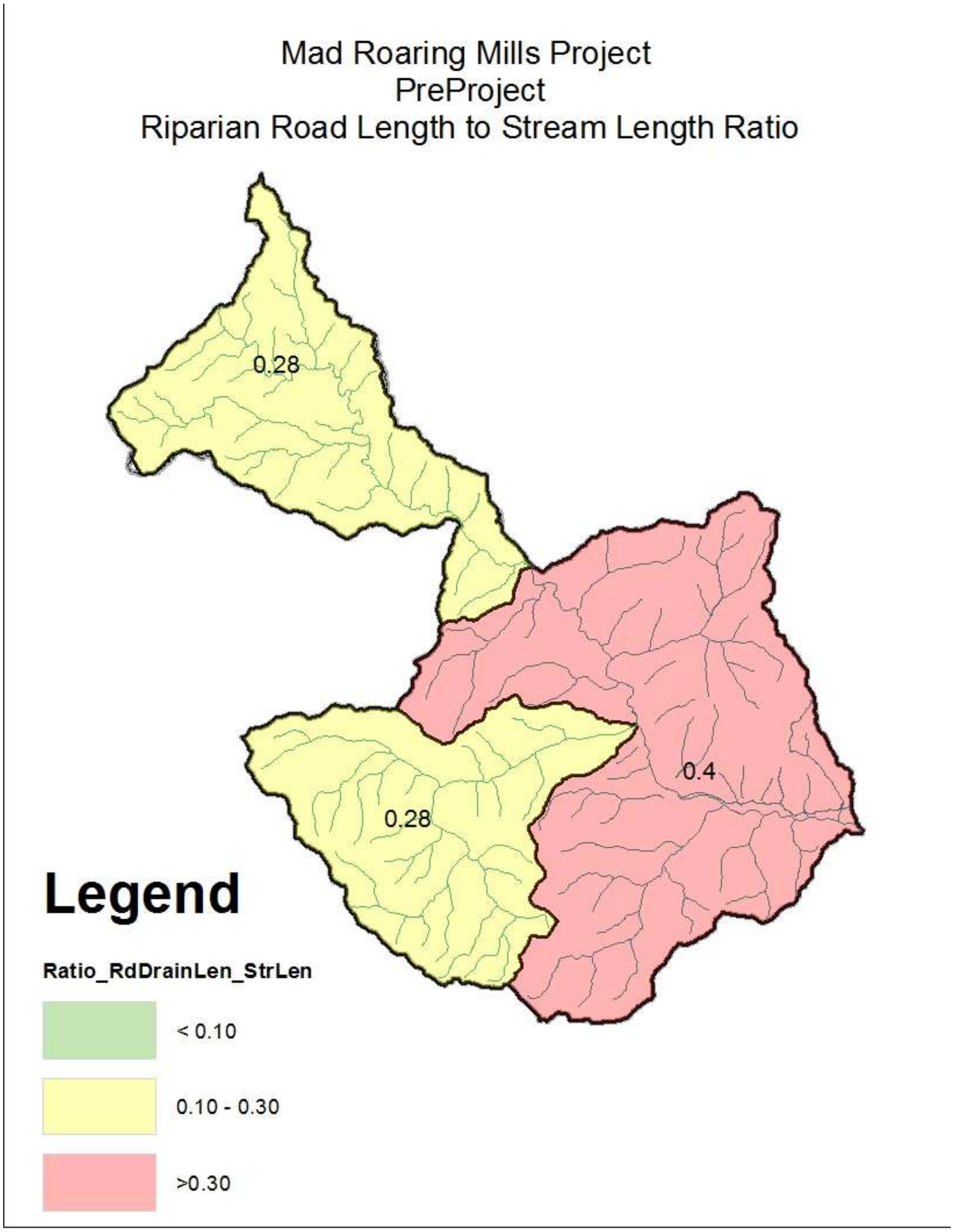

Figure 3: Ratio of riparian road network to stream length across Mad Roaring Mills project sub-watersheds.

Road crossings per stream mile was calculated as total stream crossings (fords, culverts, bridges) on open and closed NFS roads within each catchment. Both the number of stream crossings and stream crossings per mile of stream classified for catchments within the project area are shown in Figure 6. All of the sub-watersheds are rated as functioning.

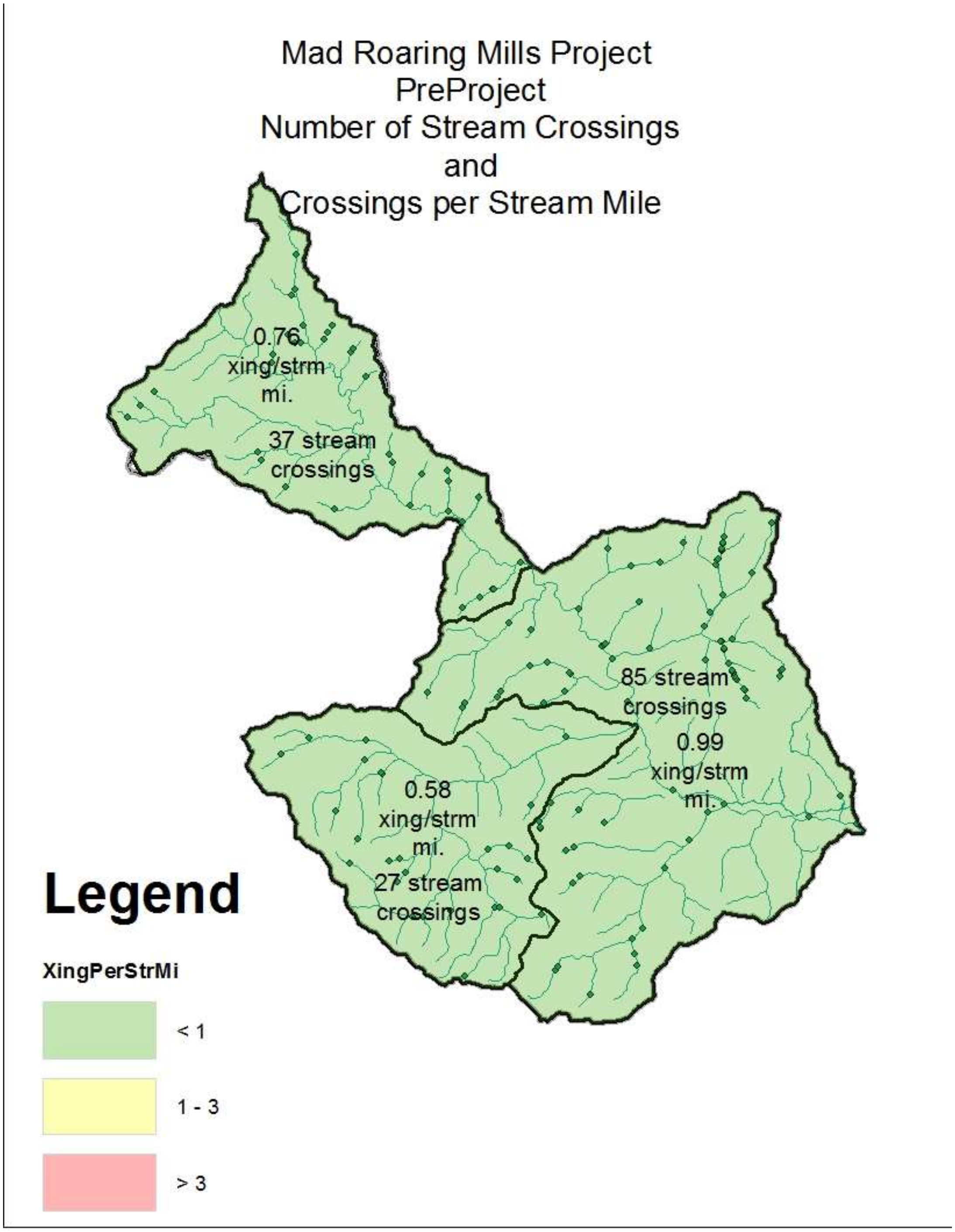

Figure 4: Number of stream crossings per mile of within the project area.

Intrinsic landscape sensitivity based on erosion and sedimentation potential was included in this analysis because the potential impact of roads to the hydrologic system is greater in areas that are more susceptible to erosion and sedimentation based on underlying geology and physiography based on SSURGO erosion risk (kwfact) ratings. The methodology to determine intrinsic landscape sensitivity is outlined in Day 2014. Intrinsic landscape sensitivity is shown in Figure 7.

Figure 5: Erosion and sedimentation risk for the project area sub-watersheds based on analysis of SSURGO kwfact. Values below 0.2 are considered low, those above 0.28 are considered high.

Incomplete and Unavailable Information

Direct and indirect effects in this analysis are modeled based on field verification and spatial data. Numbers are presented as a means to establish baseline conditions and analyze the factors influence watershed condition. Numbers are presented as a means to compare potential effects across alternatives, not as absolute values.

Methodology for Calculation of Measures

The calculation methodology and rationale for inclusion of individual measures in the hydrologic effects analysis for the Mad Roaring Mills project are shown in Table 4.

Table 4: Methodology for calculation of measures.

Resource Element	Measure	Calculation Methodology and Scale	Rationale for Including in Analysis
Water quality	Road Density	Miles of open and closed National Forest System (NFS) roads divided by total sub-watershed square miles for each sub-watershed in the project area.	Road density is a useful metric that provides a general summary of potential impacts from the road system to the hydrologic system. Other metrics included in this analysis provide a more succinct measure of potential impacts from the road system to the hydrologic system.
	Riparian road density	Miles of open and closed NFS road within 300ft of perennial and intermittent streams divided by square miles of land within 300ft of perennial and intermittent streams in the sub-watersheds of the project area.	Riparian road density provides a more targeted summary of the potential effects of the road system on hydrologic function than overall road density.
	Miles of hydrologically connected roads	Miles of open and closed NFS road that are hydrologically connected to the stream system (water and sediment from the road are delivered directly to the stream system) were determined through spatial terrain analysis and length of roads that drain into stream crossings and other drainage sources in sub-watersheds of the project area	Hydrologically connected roads present the greatest risk to the hydrologic system and are the primary focus of treatments to improve watershed condition in sub-watersheds of the project area.
	Miles of road within areas with high erosion potential	Miles of open and closed NFS roads located in areas with high intrinsic erosion potential determined through the process outlined in Day 2014.	Roads in areas where erosion and sedimentation risk is high present a greater risk to the hydrologic system than roads in areas with moderate to low erosion and sedimentation potential.

	Number of road-stream crossings	Total number of stream crossings on all open and closed NFS roads in the sub-watersheds of the project area.	Road stream crossings are areas where water and sediment from the road system are delivered directly to the stream system. In addition, undersized crossing increase the risk of the effects of potential culvert failure.
	Acres where fire risk is reduced	Total acres of fuels reduction treatment that would be completed across the sub-watersheds of the project area.	Fuels reduction treatments reduce the potential hydrologic effects from severe wildfire.
	Acres of floodplain and wetland condition restored	Total acres of floodplain treatment is calculated based on total acres of road decommissioned within 300 feet of perennial and intermittent streams.	Treatments within floodplains improve riparian function and channel morphology.
Riparian Function and Channel Morphology	Miles of stream channel restored	Total miles where stream restoration projects would be completed within sub-watersheds of the project area.	Stream restoration treatments improve riparian function and channel morphology.
	Miles of road in riparian reserves	Total miles of open and closed NFS roads within riparian reserves across the sub-watersheds within the project area. Riparian reserve width varies based on stream channel type (Table 5).	This metric provides a summary of the degree to which roads have impacted riparian function.

Affected Environment

Existing Condition

Setting

Physiography

The Mad Roaring Mills project area is in the Northern Cascade Mountains East Slope Ecoregion and experiences greater temperature extremes and less precipitation than the west slope of the Cascades. The terrain is rugged consisting of long, slightly convex steep slopes (60%-90%) with incised drainages that have developed a pincer dendritic drainage pattern. Elevation ranges from about 705 feet near the Columbia River to about 5,790 feet at the divide with the Wenatchee River Basin.

Geology

The south west of the Entiat River, project area is formed largely of Swakane biotite gneiss, amphibolite and fine to medium grained hornblende schist. Scattered pods and lenses of ultramafite and talc occur sporadically in the basin and can contribute fine sediments into the system. While the northwestern half of the project area consist of Mesozoic granitic rocks. Isolated mass wasting deposits occur throughout that project area.

Climate

Precipitation in the project area is snow-dominated with 75% of total yearly precipitation falling as snow from November-March, and 13% falling from April-June. Average annual precipitation is about 36 inches and varies based on elevation. The watershed is snow dominated with almost 75% of the precipitation falling from November through March with under 13% falling in April-June. July and August are the driest months recording about 3.5% of the average annual precipitation. Maximum snowpack (snow water equivalent) occurs by the end of March sustained snowmelt beginning by mid-April and running through May.

Average monthly temperatures (1990 – 2012) range from a low of 23.6 ºF in December to a high of 60.9 ºF in July. Average maximum monthly values range from 29.7 ºF in December to 76.8 ºF in July. Average minimum monthly values range from 19.2 ºF in December to 48.2 ºF in August (USFS 2012).

Past and Present Land Use

Under the National Forest Land and Resource Management Plan (1989) the land management allocation in the Tillicum watershed is primarily General Forest (51%) and under the Northwest Forest Plan (1994) the land allocation is primarily Matrix (56%). Approximately 21% of the watershed is privately owned with Longview Fibre Timber Company being the primary owner. These lands are intermixed, checkerboard style, within NFS lands (USFS 2012).

Vegetation management and associated road building, recreation, and sheep grazing are the historic and current land use activities on National Forest lands in the project are. In the last 50 years, thinning/pruning; planting; salvage harvest; and prescribed burning are the primary vegetation management activities. The area has been subjected to many large fires over the years, most notably in 1970, 1988, 1994, and 2014. These major fires have together covered almost the entire project area.

Recreation uses include dispersed camping, motorized road use in the summer, hunting in fall, and snowmobiling in the winter. There are no system trails, however roads are maintained, groomed and utilized for snowmobiling in the winter months.

Surface Water Characteristics

Climate, geology, and physiography are large-scale drivers of hydrologic processes, and control hydrologic regime and stream channel characteristics. Major streams in the project area include Mad River, Hornet Creek, Tamarack Creek, Roaring Creek and Mill Creek and the Entiat River. Streams in the project area have a snow-melt flow regime with a peak in flow from May-June during spring snowmelt and no discernable peaks in discharge from fall/winter rains.

The annual hydrograph from 72 years of gage data on the Entiat River near Ardenvoir shows the typical seasonal discharge pattern for streams with the project area (Figure 9).

The fisheries report discusses stream channel characteristics of specific streams in the project area.

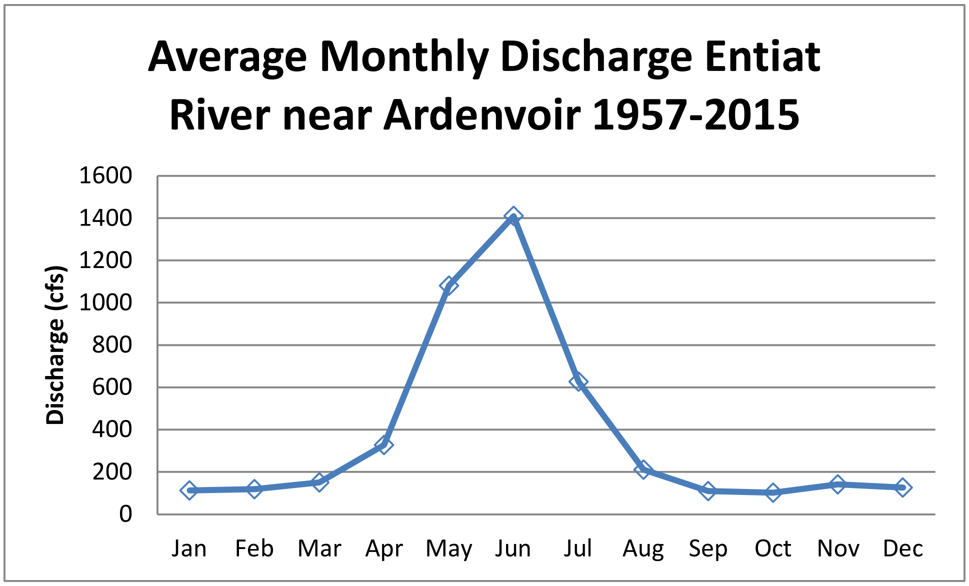

Figure 6: Average annual discharge at Entiat River near Ardenvoir (USGS 2015).

Water Quality

Climate, topography, geology/soils and topography interact to affect runoff, erosion, and ultimately water quality and quantity, riparian function, channel morphology and watershed condition (Figure 10) (Elliot 2010). Existing condition for water quality in this report is described in terms of watershed processes and land uses that affect water quality, including upland vegetation condition, vegetation management, wildland fire, insect and disease outbreaks, grazing, roads, and watershed restoration.

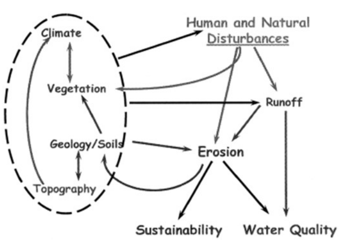

Figure 7: Physical and biological variables that control forest watershed processes (Elliot 2010).

The Role of Upland Vegetation Condition in Hydrologic Processes

Forest vegetation plays a significant role in hydrologic processes (Figure 11) (Hubbart 2007). In an intact forest ecosystem when precipitation falls as rain, vegetation intercepts a percentage of water that evaporates back into the atmosphere. Un-intercepted precipitation falls to the forest floor, where uncompacted soils and the vegetative litter layer allow water to slowly infiltrate into the soil. Infiltrated water enters the groundwater system where it is used by plants and other organisms, and is transpired back into the atmosphere through plant photosynthesis. Infiltrated groundwater eventually flows back onto the surface, feeding streams, lakes, rivers, springs, and other surface waters. A small percentage of precipitation may not be intercepted or infiltrated and may travel overland in a process known as overland flow. Overland flow is limited on forested lands with little disturbance to locations where precipitation intensity exceeds infiltration capacity (Horton overland flow), when soils are saturated and precipitation continues to fall (saturation excess overland flow), or disturbance results in soil compaction or loss of ground cover.

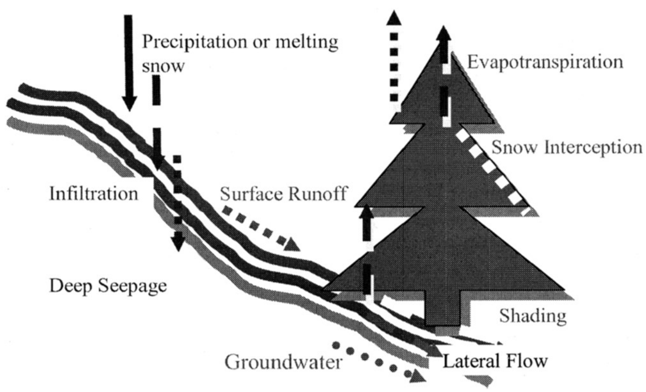

Figure 8: Hydrologic hillslope processes in forested ecosystems (Elliot 2010).

Precipitation falling as snow is associated with climatic processes, but is also dependent on forest cover. In winter, trees intercept significant amounts of snow that often sublimates (changes directly from solid to gas state) and never reaches the ground, reducing the amount of precipitation available to infiltrate or run off the landscape (Elliot 2010). Creation of canopy openings can alter rates of snow accumulation and alter the timing of snowmelt (Troendle and King 1985). Troendle et al. (2001) report that in coniferous forests in cold snow zones 25-35% of snow will be intercepted and sublimated or evaporated. Studies have shown that snow water equivalent and snow melt rates are higher in open areas than in forested areas (McCaughey and Farnes, 2001, Skidmore et al. 1994). In a study in northern Idaho, measured snow water equivalent was 200mm less under a canopy than in an open area (Hubbart 2007).

The effect of changes in upland vegetation on hydrologic function is dependent on the processes through which changes in vegetation cover affect water cycle components, including evapotranspiration, snow accumulation and melt rates, infiltration, and overland flow (Chamberlin et al. 1991). Removal of canopy cover through timber harvest, insect and disease outbreaks, or wildland fire alters the hydrologic cycle by reducing interception by vegetation, altering evaporation and transpiration. Removal of vegetation and organic matter from the forest floor can also increase watershed runoff, erosion, and sedimentation. Removal of leaf litter and other vegetation material from the forest floor also increase runoff and erosion and sedimentation processes (Robichaud et al. 1993). Removal of forested vegetation can also affect water yield and peak flows. Reduction in canopy cover interception and evapotranspiration can increase the amount of precipitation available and the timing of runoff and recharge to surface water systems (Goodell, 1965, Woods 1966).

Timber Harvest

There is no commercial timber harvest included in the Mad Roaring Mills project, but there would be non-comercial thining and vegetation management projects. Effects of vegetation removal are included in this report based on potential impacts of past vegetation management on current watershed processes in the project area.

Direct removal of vegetation through timber harvest can affect watershed processes including runoff, erosion, and sedimentation, water yield, and peak flows, however the infrastructure to support vegetation removal has the greatest impact to hydrologic processes and function. Furniss et al. (1991) concluded that forest roads contribute more sediment than all other forest activities combined on a per-unit area basis

(Meehan 1991). The majority of sediment from timber harvest activities is related to road construction and increased use of existing roads (Lee et al. 1997, Chamberlain et al. 1991, Dunne and Leopold 1978).

Removal of trees through timber harvest can also affect water yield. Studies on the effects of vegetation removal on water yield show highly variable effects, and generally have not been undertaken on a scale greater than small watersheds (Ziemer 1987). At small scales, changes in water yield are easier to measure, while changes in runoff per unit area are hard to measure directly for larger areas because changes are too small for direct measurement (Huff et al. 2000). In conifer forests a reduction in forest cover less than 20%, resulted in no detectable increase in water yield (Bosch and Hewlett 1982; Stednick 1996). Megahan et al. (1995) found no significant increase in either annual or monthly streamflow in a paired catchment study in Idaho, where 23% of one watershed was clearcut through helicopter-logging and burned. A study on a clear-cut in 25% of the study basin in the Uinta Mountains of Utah found up to a 147mm (52%) increase in annual water yield with the largest increases in May-August. Increases in water yield persisted for the 20 years data was collected after harvest (Burton 1997). A 30-year study of watershed response to timber practices at the High Ridge evaluation area in the Northern Blue Mountain showed low-magnitude, short-term increases in water yield after clear cutting (Helvey et al. 1995).

The greatest relative increases in water yield and streamflow from vegetation removal in the Pacific Northwest are observed in the summer low-flow season, however larger overall increases occur during snowmelt (Harr 1979; Troendle et al. 2001; Brown et al. 2005). In a study in northwestern California, Keppeler and Ziemer (1990) found that relative water yields were greater during summer low-flow, than annual flows, with increases diminishing 5 years post-harvest.

Generally water yield increases in proportion to forest vegetation removed, with lower magnitude in response in dry regions (Stednick 1996; Brown et al., 2005). Water yield typically increases in the first year following fire or logging, but slowly decreases to pre-disturbance levels as vegetation reestablishes (Hibbert 1967; Peterson et al. 2009). The magnitude of increases in water yield is dependent on precipitation patterns 2-3 years after disturbance as vegetation begins to recover. The duration of water yield and peakflow increases following vegetation removal or mortality is dependent on timing and intensity of precipitation and snowmelt rates (MacDonald 2000), and rate of vegetation recovery. Areas with high precipitation generally have vegetation regenerate resulting in the rapid return of streamflow to pre-disturbance state. However, these same higher-precipitation watersheds also have the most pronounced, yet short-lived increase in water yield (Stanley and Arp 2002). Therefore, short-term increases in water yield may be more pronounced on the western higher elevation portions of the project area. Smaller magnitude increases in water yield would be expected in the drier eastern section of the project area, however these effects may be longer in duration, as vegetation may take longer to reestablish.

While small scale studies show that water yield can be increased through focused forest management, the scale of treatment needed to increase water yield on NFS lands is constrained by a variety of factors. Only portions of areas on NFS lands can be economically treated based on physical, environmental, and political constraints (Ziemer 1987). Although it has not been studied locally, a 1983 study for NFS lands in the Sierra Nevada Mountains of California found that if multiple use/sustained yield guidelines were followed, water yield could be increased by 1% above current levels (Kattelmann et al. 1983). This increase would likely be undetectable from a water use perspective; US Geological Society stream gages usually have up to a 5% error (Rothacher 1970). In addition, most of the projected increases would occur during snowmelt in wetter years, rather than during summer low-flow and in drought years.

Vegetation removal also affects peak flows. In a compilation of paired and modeled watershed studies in western North America, the largest increases in peak flows were reported for small storms (<1 year recurrence interval), with increases in peak flows diminishing with higher magnitude storms (Grant et al.

2008). The largest peak flow increases were in watersheds that had been 100% clearcut, but there was no pattern between treatment type and magnitude of peak flow increase (Grant et al. 2008). While vegetation treatment type affects peak flow, other management treatment considerations including road density, hydrologic connectivity, and drainage efficiency (Wemple et al. 1996), and riparian buffer widths also influence peak flows (Grant et al. 2008). Increased erosion and runoff from forest roads generally have a greater influence on peak flows than vegetation removal (Wemple et al. 2001).

Wildland Fire

Wildland fire includes both unplanned and planned initiations (prescribed fire). Prescribed fire is initiated to achieve resource management objectives, primarily to reduce the risk of high severity fires. Small-scale, low intensity wildland fire was once a common occurrence in forest lands across the Okanogan-Wenatchee National Forest, however fire exclusion since the early 1900s has resulted in changes in forest structure and species composition resulting in increased risk of higher severity and intensity wildfires when they do occur (Hessberg and Smith 1999). Fire severity describes the effects of a fire to soil structure, infiltration capacity and biotic components and affects runoff and soil erosion potential from fire effects. Fire intensity describes fire effects to vegetative characteristics including tree mortality and consumption of understory vegetation and down wood (Debano et al. 1998) and affects runoff rates, peak flows, water yield, and riparian canopy cover.

Insects and Disease

Large-scale insect and disease outbreaks can have similar effects to hydrologic function as large scale wildland fire in the scale of disturbance and mortality of overstory vegetation (Wondzell 2001). Increase in dead trees may increase fuel loading and increase susceptibility to large fires (Hessberg et al. 1994). There are limited studies on the effects of die-off from insect and disease outbreaks on erosion and sedimentation, but indirect effects include increased inputs of litter to the forest floor, and increased large woody debris to the stream system and upland environment (Wondzell 2001). Die-off from insects and disease can also alter water yield and peak flows through the same processes discussed in the Timber Harvest and Wildland Fire sections of this report. Adams et al. (2012) hypothesize that in snowmelt-dominated watersheds, there will be decreases in evapotranspiration and increased flows if canopy cover from die-off exceeds 20%.

Roads

Roads are the primary driver of impaired hydrologic function in the project area. Road density ranges from 2.54 to 3.04 mi/mi^2, riparian road density ranges from 2.48 to 3.52 mi/mi^2, and there are an estimated 13 to 36 miles of hydrologically connected roads for respective sub-watershed and from 37 to 85 road-stream crossings across the sub-watersheds. The following section provides a description of why the road system is preventing attainment of desired conditions.

Roads have wide-ranging effects on hydrologic processes and watershed function. The compacted surface of roads lowers infiltration capacity, which alters and concentrates overland flow and increases erosion and delivery of sediment to the stream system, which can degrade water and habitat quality (Furniss 1991). Roads can also intercept subsurface flow and convert it to rapid surface runoff, extending channel networks and increasing watershed efficiency (Wemple et al. 1996). Roads reduce vegetative cover in streamside areas and accelerate delivery of water and increase erosion and sedimentation into streams (Megahan, 1983). Accelerated erosion, runoff, and sediment delivery from roads increases streambed fine sediment, which affects aquatic habitat and macroinvertebrates, and makes streambeds and banks more susceptible to erosion during high flow events (Cover et al. 2006). At crossings, excessive flow velocities and undersized culverts can alter stream channel function and increase the risk of channel and crossing instability at high flows (Furniss et al. 1998). Other road-related impacts include reduced potential large wood available for in-channel wood and shade from riparian areas. Meredith *et al.* (2014) found the presence of roads adjacent to streams reduced adjacent in-channel wood.

Slope position of roads is a critical factor in the interaction between roads and streams. Ridge-top roads can influence watershed hydrology by channeling flow into small headwater swales, accelerating channel development. Mid-slope roads can intercept subsurface flow, extend channel networks, and accelerate erosion (Gucinski et al., 2001). Roads adjacent to and crossing streams, or hydrologically connected to streams have the greatest influence on streamflow, streamside shade, and accelerated sediment delivery to the stream system (Croke et al 2005). Hydrologically connected roads (portions of roads that route water and/or sediment directly to the stream system) increase flow routing efficiency and can increase peak flows and sedimentation (Wemple et al. 1996). Roads also simplify adjacent channels and riparian and in-stream habitat, and prevent natural channel adjustments (Spence et al. 1996).

Several road metrics provide a means to assess the potential effects and risk of roads. Road density is often used as a measure of risk particularly in areas of active timber harvest (Lee et al. 1997, Sharma and Hilborn 2001). Road densities of <1 mi/mi^2 with no valley bottom roads are considered low enough to support proper watershed and aquatic function (Potyondy and Geier 2010). Road densities of 1 to 2.4 mi/mi^2 are considered functional at risk, and road densities >2.4 mi/mi^2 are considered not functional. However, road density may not adequately assess the varying effects of roads across the landscape that are dependent on geology, precipitation, and location of roads in relation to the stream system (Lee et al. 1997). McCafferty et al. (2007) found a significant positive correlation between total road density, open road density, number of stream crossings, and fine sediment in streams. Traffic density on open roads can also present a larger erosion and sedimentation risk than closed roads. Reid and Dunne (1984) found that a heavily used road segment contributes 130 times as much sediment as a closed road.

Decommissioned roads were also included in this analysis because spatial data does not include detail on the level of hydrologic decommissioning completed on decommissioned roads. Therefore, decommissioned roads are assumed to have a continued effect on the hydrologic system. Since they are used for one-time access as needed in a single timber sale or associated project, temporary roads were not included in this analysis. However, temporary roads can have an impact on hydrologic and aquatic function if they are not properly removed and stabilized following use.

Hydrologically connected roads and crossings are a higher risk to the stream system than mid-slope and ridgetop roads because they deliver water and sediment directly to the stream system. Several tools and models can be used to assess the relative hydrologic risk of the road system, and determine the location of roads were risk could be minimized through focused restoration and road improvements. One tool is the field and model based Geomorphic Road Analysis and Inventory Package (GRAIP). Road sediment delivery data collected across four watersheds in the Pacific Northwest using GRAIP, including the NF Siuslaw and NF John Day watersheds in Oregon and the Bear Valley and the MF Payette watersheds in Idaho, found that 2-10% of road drain points (depending on watershed) deliver 90% of sediment from the road to the stream system (Figure 12) (GRAIP 2014). Results of this analysis suggest that when the location and relative sediment production and delivery of high-risk roads is known, treatments can focus on a relatively small percentage of the road system to reduce hydrologic impacts.

While GRAIP was not used to determine and prioritize treatments for the project area, road treatments in the project focus on the subset of roads that are causing the greatest impact to hydrologic function and aquatic habitat. Similar to the results of GRAIP across 4 western watersheds, the process to prioritize road treatments in the project area showed that a relatively small percentage of roads in the watershed presented the greatest risk to hydrologic function and aquatic habitat.

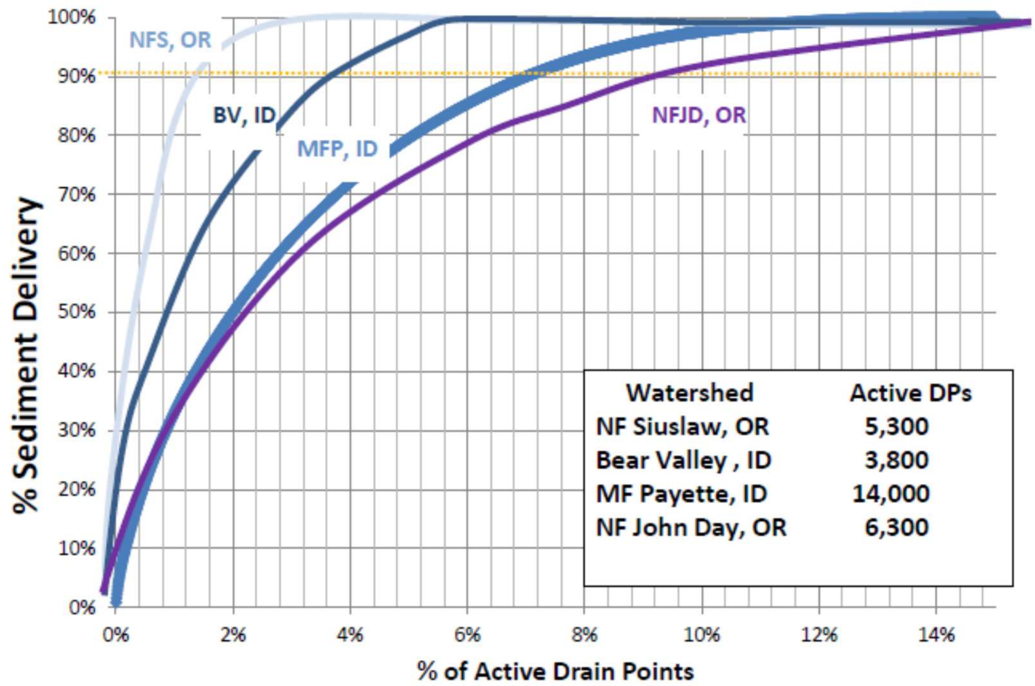

Figure 9: Road sediment delivery in four watersheds in the Pacific Northwest (GRAIP 2014).

Riparian Function and Channel Morphology

Riparian Function

Although riparian areas comprise a small portion of lands in the project area, they provide important ecological function and habitat for plants and aquatic and terrestrial wildlife (Wissmar 2004). Riparian areas provide a linkage between upland and stream habitats and are important habitat for aquatic and terrestrial wildlife and a variety of plants. Vegetation production is generally higher in wetland and riparian ecosystems than in the uplands, and riparian structure and function influence the rate, amount, and timing of discharge of water, sediment, nutrients, and other potential pollutants (Kovalchik and Clausnitzer 2004).

Riparian areas act as a filtration system for overland water and sediment runoff before it enters the stream system. This function is especially important where watersheds have experienced disturbance or management that alters the routing of water and sediment upslope of the riparian area. Trees and shrubs in riparian areas create shade, regulate air, soil, and water temperature, and provide inputs of downed trees and woody debris to the stream system (Wissmar 2004). Roots of riparian vegetation provide bank stability and slow the rate of erosion and potential channel migration (Gregory et al. 1991). Riparian vegetation also slows flowing water during high flow events, trapping sediment within the floodplain (Platts et al, 1985), resulting in a reduction in the sediment load in flood water (Wondzell 2001).

The Northwest Forest Plan (USDA Forest Service 1994) designates riparian reserves to be managed for the benefit of aquatic and riparian-dependent species. Since riparian reserves are designated by width rather than riparian function or existence of riparian vegetation, there is often upland vegetation on the outer width of riparian reserves. Riparian reserve widths vary based on stream/wetland type. Total riparian reserve acres by sub-watershed are shown in Table 5.

Table 5: Acres of riparian reserves by sub-watershed

	Stream and Waterbody Classification	Acres
Lower Mad River		
	Fish Bearing 300ft	971.4
	NoFish Perennial 150ft	506.8
	NWFP-NoFish Intermittent 100ft	413.7
	NWFP-Wetlands < 1 Acre 100ft	3.6
	NWFP-Wetlands >= 1 Acre 150ft	59.5
Mills Creek – Entiat River		
	NoFish Perennial 150ft	187.7
	NWFP-NoFish Intermittent 100ft	712.3
	NWFP-Wetlands < 1 Acre 100ft	5.8
	NWFP-Wetlands >= 1 Acre 150ft	38.1
Roaring Creek		
	Fish Bearing 300ft	457.3
	NoFish Perennial 150ft	196.8
	NWFP-NoFish Intermittent 100ft	396.2
	NWFP-Wetlands < 1 Acre 100ft	3.4
	NWFP-Wetlands >= 1 Acre 150ft	49.4

Historical and current uses in riparian areas in sub-watersheds within the project including roads, dispersed recreation, historic logging practices, and wildfires have influenced the structure, composition, and function of riparian areas.

Water Rights and Uses

There are 17 certificated water rights, permits, or claims on NFS lands in the project area. Primary water uses include water for instream flows, stockwatering, road watering, and fire suppression.

Watershed Condition

<u>Watershed Condition</u>

A fundamental goal of the Forest Service is "To protect NFS watersheds by implementing practices designed to maintain and improve watershed condition, which is the foundation for sustaining ecosystems and the production of renewable natural resources, values, and benefits" (FSM 2521). Watershed condition is defined as "The state of the physical and biological characteristics and processes within a watershed that affect the hydrologic and soil functions supporting aquatic ecosystems" (Potyondy and Geier 2010). Properly functioning watersheds have five characteristics (Williams et al. 1997, and Potyondy and Geier 2010):

1. Provide for high biotic integrity, and support adaptive animal and plant communities that reflect natural processes;
2. Resilient and recover rapidly from natural and human disturbances;
3. Exhibit a high degree of connectivity along the stream both laterally across the floodplain and valley bottom, and vertically between surface and subsurface flows;
4. Important ecosystem services including high water quality, recharge of streams and aquifers, maintenance of riparian communities, and resiliency to climate variability and change;
5. Maintain long-term soil function.

The Watershed Condition Framework (WCF) was conceptualized at the National scale to change the Forest Service's approach to landscape and watershed restoration. The WCF established a nationally-consistent approach to classify watersheds based on underlying ecological, hydrological, and geomorphic functions and targets implementation of focused restoration activities in priority sub-watersheds. The WCF provides outcome-based performance measures for documentation of improvement in watershed condition at Forest, Regional, and National scales (Potyondy and Geier 2010).

National Forests throughout the U.S. implemented the WCF process in 2010. Sub-watersheds on the Okanogan-Wenatchee were classified into three categories through the WCF based on classes described in FSM 2521.1 and Potyondy and Geier (2010):

- Class 1: Functioning Properly—SWSs that exhibit high geomorphic hydrologic, and biotic integrity relative to natural potential conditions. The watershed is functioning similar to natural wildland conditions (Karr and Chu 1999, Lackey 2001). There are minimal adverse human impacts on natural physical or biological processes, and the watershed is able to naturally recover to previous condition in response to natural and human disturbance (Yount and Neimi 1990);
- Class 2: Functioning at Risk—SWSs exhibit moderate integrity as described above;
- Class 3: Impaired Function—SWSs exhibit low integrity as described above. Adverse human impacts have caused a threshold to be exceeded where the watershed is no longer as resilient to physical and biological processes.

Sub-watersheds are classified by WCF based on geomorphic, hydrologic, and biotic integrity relative to potential natural condition, which relates to geomorphic, hydrologic, and biological watershed function. Integrity is evaluated in the context of the natural disturbance regime and geoclimatic setting and includes aquatic and terrestrial components because water quality and aquatic habitat are related to the integrity and functionality of the upland and riparian areas across the watershed (Potyondy and Geier 2010). The WCF includes 12 indicators comprised of attributes that represent underlying ecological function and processes that affect soil and hydrologic function (Potyondy and Geier 2010).

The WCF assessment ranked all of the sub-watersheds as "*functioning at risk*" based on the extensive road network as well as past and ongoing management activities including commercial timber harvest within riparian areas, sheep grazing, historic stream channel straightening, and removal of large wood from the creeks.

Management Direction

Forest Plan

The Final Environmental Impact Statement for the 1990 Wenatchee National Forest Land and Resource Management Plan (LRMP), as amended by the Record of Decision for the Amendments to the Forest Service and Bureau of Land Management Planning Documents within the Range of the Northern Spotted Owl (Northwest Forest Plan- NWFP, 1994, 2001) provide broad management direction for the Mad Roaring Mills Project. The Mad Roaring Mills Project is compliant with both the Wenatchee LRMP, and the Northwest Forest Plan.

Okanogan-Wenatchee Forest Restoration Strategy

The Mad Roaring Mills Project is part of the Okanogan-Wenatchee National Forest's strategic, landscape-scale approach to vegetation management project planning described in the 2012 Forest Restoration Strategy with a long-term goal of forests and watersheds that are resilient to disturbances and climate change. A landscape analysis using the Ecosystem Management Decision Support (EMDS) tool helped define treatment needs and established the context of the project within the broader landscape. The

EMDS analysis displayed the relative departure of existing vegetative conditions to desired conditions, the susceptibility to uncharacteristic wildfire and the ability to support focal wildlife species.

Other Guiding Documentation

Several documents for the project area sub-watersheds and the Entiat subbasin outline activities to improve watershed function and aquatic habitat. The activities within Mad Roaring Mills Project follow direction outlined in guiding documents, including:

- *Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan* (Upper Columbia Recovery Board (UCSRB) 2007)
- *A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region* (Draft) (Upper Columbia Regional Technical Team (UCRTT), 2007)
- *USFWS Bull Trout Final Critical Habitat Rule* (September 2010; the Rule identifies Tillicum Creek as essential spawning and rearing habitat for the Entiat and Mad River local populations)
- *Chapter 22, Upper Columbia Recovery Unit, Washington. In*: U.S. Fish and Wildlife Service. Draft Bull Trout (*Salvelinus confluentus*) Recovery Plan. 113 p. (U.S. Fish and Wildlife Service, 2002)
- *Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl* (Northwest Forest Plan, 1994) (Tillicum sub-watershed identified as a Level I Key Watershed (part of the Lower Mad sub-watershed)
- *Entiat Water Resource Inventory Area* (WRIA) 46, (Cascadia Conservation District (CCD) 2004)
- *Detailed Implementation Plan, Entiat Water Resource Inventory Area* (WRIA) 46, (Cascadia Conservation District (CCD) 2006)
- *Watershed Assessment, Entiat Analysis Area* (USFS 1996)

The Draft Okanogan-Wenatchee National Forest: Procedures for Watershed and Aquatic Resource Assessment, Analysis and Proposal Development for Whole Watershed Scale Projects (OWNF 2015) was used to analyze and develop the Tillicum Watershed Restoration Project.

Clean Water Act

The principal law governing pollution in the nation's streams, lakes, and estuaries is the Federal Water Pollution Control Act (P.L. 92-500, enacted in 1972), commonly known as the Clean Water Act (CWA). The CWA is the primary federal law that protects the nation’s waters, including lakes, rivers, aquifers and coastal areas from point and non-point source pollution. The primary objective of the CWA is to restore and maintain the integrity of the nation's waters through regulation of point and non-point source water pollution.

Through the CWA, each state is required to provide guidance and direction for the protection and restoration of water bodies (40 CFR 131.12). In Washington, the United States Environmental Protection Agency (EPA) has designated authority for compliance with the CWA to The Washington Department of Ecology (hereafter referred to as “Ecology”). As required under the CWA, Ecology identified beneficial uses and developed water quality standards to protect beneficial uses at the scale of Water Resource Inventory Areas (WRIAs) which generally correlate with subbasins across Washington State. Water quality standards in Washington are designated at the WRIA-scale. Water quality standards for the primary pollutants on streams and rivers in the Entiat WRIA 46 are shown in Table 6.

Table 6: Water quality standards for waters in the Mad Roaring Mills project sub-watersheds (WAC 173-201A-200).

Parameter	Standard
Temperature	12°C (60.8°F) (7 day average of daily maximum temperature)
pH	6.5-8.5, with a human-caused variation within the above range of <0.2 units.
Fecal Coliform	geometric mean above 50 colonies per 100 milliliters with the 90th percentile of the samples not exceeding 100 colonies per 100 milliliters
Dissolved Oxygen	9.5 mg/L (lowest 1-day minimum)
Total Dissolved Gas	Shall not exceed 110% of saturation at any point of sample collection
Turbidity	5 NTU over background when background is 50 NTU or less. A 10% increase in turbidity when background turbidity is more than 50 NTU.

Designated beneficial uses include (WAC 173-201A-200):

- Salmon and trout spawning, core rearing and migration
- Extraordinary primary contact recreation
- Domestic, industrial, and agricultural water supply
- Stock watering
- Wildlife habitat
- Harvesting (fish, etc)
- Commerce and navigation
- Boating
- Aesthetic values

Section 303(d) of the Clean Water Act and EPA regulation (40 CFR 130.2(J), and 130.7), delegates the authority to list waters that do not meet water quality standards or beneficial uses to individual states. Washington determines its 303(d) list through the water quality assessment process. Once a water body is listed as impaired on the 303(d) list, it is Ecology's responsibility to develop a Total Maximum Daily Load (TMDL) for each pollutant of concern. A TMDL is a quantitative plan and analysis procedure for attaining and maintaining water quality standards and specifies the total load of pollutant a waterbody can carry and still meet beneficial uses. The TMDL and associated Water Quality Implementation Plan (WQIP) outline the process through which beneficial uses can be met through the identification of sources of pollutants, and actions that lead to improved water quality (40 CFR 130.2(H)). The Entiat River near the mouth is the only stream segment listed in the most recent approved 303(d) list in the project area. This segment is listed for excursions of the pH criteria.

A 2000 Memorandum of Agreement (MOA) between Ecology and Region 6 of the U.S. Forest Service designates the USFS as the management agency for meeting CWA requirements on NFS lands. Through this MOA the FS is responsible for ensuring that all waters on NFS lands meet or exceed water quality laws and regulations and that activities on NFS lands are consistent with protections provided in Washington Administrative Code and relevant state and water quality requirements (USDA FS and WADoE, 2000). The MOA recognizes the contribution of existing FS direction, including the Interior Columbia Basin Ecosystem Management Project (ICBEMP), INFISH, and BMPs in meeting water quality laws and regulations, and states that the Forest service and Ecology will collaborate to address 303(d) listings through the development of TMDLs and WQIPs (USDA Forest Service and WADoE, 2000). While the 2000 MOA has not been updated, the Okanogan-Wenatchee National Forest and Ecology continue to manage CWA compliance under this MOA.

Environmental Consequences

Potential effects of the alternatives are analyzed and compared in terms of how project treatments (roads, fuels, stream channel restoration, and riparian improvement) affect water quality, riparian function and channel morphology, and watershed condition.

Alternative 1 – No Action

Resource elements and measures for the no action alternative (existing condition) are shown in Table 7.

Table 7: Resource elements and measures for the no action alternative.

Resource Element	Measure	No Action (Lower Mad River, Mills Creek, Roaring Creek)
Water quality	Road Density	2.56, 3.04, 2.54 mi/mi^2
	Miles of hydrologically connected roads	13.3, 36.2, 13.9 miles (63.4 total)
	Riparian road density	2.48, 3.52, 2.5 mi/mi^2
	Miles of road within areas with high erosion potential	16.1, 38.4, 21.3 mi. (75.8 total)
	Number of road-stream crossings	37, 85, 27 (149 total)
	Acres where fire risk is reduced	0
Riparian Function and Channel Morphology	Acres of floodplain and wetland condition restored	0
	Miles of stream channel restored	0
	Miles of road in riparian reserves	13.4, 34.1, 13.1 mi. (60.6 total)

Water Quality

Fuels Reduction Treatments

Vegetation condition to reduce the risk of high severity fire would not be improved. High stand densities increase the risk of high severity wildfire which has the potential to cause significant degradation of water quality.

Road and Culvert Treatments

Under the no action alternative no road and culvert improvement activities would occur. The hydrologic and ecological effects of roads discussed in the existing condition section of this report would continue. Roads in unstable condition would continue to deteriorate, and sediment delivery will continue to occur, especially on hydrologically connected roads and crossings, and roads within riparian reserves. There would be no improvement of road or culvert conditions except those that occur under regular road maintenance.

Stream and Riparian Restoration

There would be no stream channel improvements within the project area under the no action alternative.

Riparian Function and Channel Morphology

Fuels Reduction Treatments

Vegetation condition to reduce the risk of high severity fire would not be improved. High stand densities increase the risk of high severity wildfire which has the potential to impact riparian function and channel morphology.

Road and Culvert Treatments

Roads within riparian reserves would not be closed or relocated. The effects of roads on riparian function and channel morphology would continue as described in the existing condition section of this report.

Stream and Riparian Restoration

Stream channel improvements in Mad and Roaring creek would not be completed under the no action alternative. There would be no improvement in riparian function or channel morphology. Number of medium and large pieces of LWD, number and quality of pools, channel substrate, and entrenchment would not be improved, and would continue to respond to existing near-stream and upland natural processes and land uses.

Watershed Condition

Watershed condition under the no action alternative would not improve. There would be no road, fuels, or stream restoration treatments. The sub-watersheds would remain “functioning at risk”, with the potential to trend toward “impaired function” if there were a large fire or an increase in road erosion and sedimentation, or mass wasting events.

Sub-watershed condition

Sub-watershed condition would remain unchanged. All sub-watersheds would be “not functional” in relation to road density and riparian road density.

Lower Mad and Roaring sub-watersheds would stay “functioning at risk” relative to increases in drainage network due to roads while Mill Creek – Entiat River remain “not functioning”.

The sub-watersheds would be “functioning” with respect to number of stream crossings with all sub-watersheds below 1 stream crossing per stream mile. The number of stream crossings ranging from 27 in Roaring Creek, 37 in Lower Mad, and 85 in Mills Creek – Entiat River.

Throughout the project area there would be 75.8 miles of roads traversing soils rated as having high intrinsic sediment delivery potential. Lower Mad River has 16.1 miles, Mills Creek – Entiat River has 38.4 miles, and Roaring Creek has 21.3 miles.

Alternative 2 – Proposed Action

The proposed action includes 10,628 acres of non-commercial fuels reduction treatment, 167 acres of mastication, piling, and pile burn, 8,133 acres of prescribed fire, and a suite of road treatments, and several measures to improve stream channel and riparian function. Road treatments in the proposed action are shown in Table 8.

Table 8: Miles of road treatment in the proposed action.

Treatment	Alternative 2 (miles)
Closure	17.3
Decommission	90.9
Convert to Motorized Trail	9.4
Upgrade	0.4
Remove Non-System	55.3

There would be 7 culverts would be upgraded and further cross drain culverts in conjunction with road decommission and closure treatments in the proposed action. Stream channel restoration and vegetation planting would occur on decommissioned roads and removed/upgraded culverts.

Project Design Features and Mitigation Measures

Implementation of best management practices (BMPs) is one of the primary mechanisms to ensure that aquatic and hydrologic function are preserved in all alternatives. Project-level monitoring of implementation and effectiveness of BMPs using nationally-consistent protocols would continue under all alternatives. BMP monitoring will be used to identify and implement corrective actions to address site-scale problems with BMP implementation and effectiveness. Accountability for addressing lack of effectiveness and implementation of BMPs is a critical component of water resource protection and compliance with the Clean Water Act.

In addition to BMPs and Forest Plan compliance all mitigation measures and design criteria described in the "Project Design Features and Mitigation Measures for Aquatic Restoration Projects in the Mad Roaring Mills project" would be implemented.

Direct and Indirect Effects

Potential direct and indirect effects are discussed together in this section. Direct effects occur at the time and place the action is implemented, and indirect effects occur off-site or later in time. Direct and indirect effects of the Mad Roaring Mills project are discussed and analyzed primarily in terms of how the project will affect watershed processes and how these watershed processes affect water quality, riparian function and channel morphology, and watershed condition. Measures to analyze potential direct and indirect effects from the Mad Roaring Mills project are shown in Table 9 and discussed below.

Table 9: Numeric measures of potential direct and indirect effects in the proposed action.

Resource Element	Measure	Alternative 2 Proposed Action (Mad River, Mills Creek,

		Roaring Creek)
Water quality	Road Density	2.0, 2.1, 2.1 mi/mi^2
	Miles of hydrologically connected roads	11.3, 29.4, 12.1 miles (52.8 miles total, 10.6 mile reduction)
	Riparian road density	2.13, 2.82, 2.21 mi/mi^2
	Miles of road within areas with high erosion potential	12.2, 35.6, 19.6 miles (67.4 miles total, 8.4 mile reduction)
	Number of road-stream crossings	29, 69, 22 (120 total)
	Acres where fire risk is reduced	10,795
Riparian Function and Channel Morphology	Acres of floodplain and wetland condition restored	13.5
	Miles of stream channel restored	2.5 miles MillsCk 1.3 miles Roaring Ck
	Miles of roads in riparian reserves	11.5, 27.4, 11.6 miles (50.5 miles total, 10.1 mile reduction)
	Watershed Condition	Functional at risk with a trend toward functional

Water Quality

Fuels Reduction Treatments

Fuels reduction on 10,795 acres would directly reduce fuels and indirectly decrease the risk of potential high severity fire in the Mad Roaring Mills project. High severity fire kills trees and decreases canopy cover, partially or completely burns ground cover, and may form water-repellant soils (hydrophobic) depending on burn intensity. Soil water storage, interception, and evapotranspiration are reduced when vegetation is removed or killed by fire and when organic matter on the soil surface is consumed by fire (DeBano et al. 1998; Neary et al 2005). Fire consumption of ground vegetation and hydrophobic soils increase overland flow and erosion and sedimentation risk. Burned areas are vulnerable to accelerated soil erosion which can increased post-fire sediment yield (Neary, et al., 2005). Increases in surface erosion following wildfire have been well documented (Helvey, 1980, Robichaud and Hungerford, 2000; Wondzell and King., 2003; and Neary et al., 2005); however, effects are spatially variable based on soil condition, burn severity, and timing and magnitude of precipitation (Robichaud and Hungerford, 2000). Helvey et al. (1985) found that annual sediment yield increased as much as 180 times above pre-fire levels following a high-mortality wildfire in the Entiat experimental forest. Water yields and peak flows can also increase from large fires due to loss of canopy cover and reduction in evapotranspiration (Helvey 1980).

Prescribed fire is used as a management tool to by itself or in conjunction with thinning to reduce fuel loading and the risk of uncharacteristically large fires (Mitchell et al. 2009). The most effective way to reduce fire severity is forest thinning in conjunction with prescribed burning (Covington et al. 1997, Graham et al. 1999). Most prescribed fires are ignited under conditions that limit the potential for high severity fires (Wondzell 2001), they have less of an effect on vegetative litter and soil organic structure, and result in a lower risk of erosion and changes in water yield and peak flows (DeBano et al. 1998).

Climate change is expected to alter fire return intervals as well as potential effects from increasingly large, severe fires. There is a close correlation with climate conditions and severity and extent of wildfires in the western U.S., and projected changes in temperatures and precipitation in the interior Pacific Northwest are expected to increase the risk of larger, more severe fires (Littell et al. 2010, Westerling et al. 2003).

Potential direct and indirect effects to hydrologic processes and water quality from non-commercial fuels treatments and prescribed fire are mitigated through BMPs and standards and guidelines that limit fire intensity and severity, ground-disturbing activities (including firelines), and retain adequate groundcover. Fuels reduction treatments on 10,795 acres of the Mad Roaring Mills project in the proposed action would increase landscape resiliency to large-scale wildland fire in the project area and would mitigate potential effects to hydrologic function and water quality.

Road and Culvert Treatments

Decommissioning of 90.9 road miles, and closure of 17.3 road miles would decrease erosion and sedimentation from the road system.

The proposed action would reduce road density in Lower Mad River sub-watershed from 2.56 to 2.0 mi/mi^2. For the Mills Creek sub-watershed road density would be reduced from 3.04 to 2.1 mi/mi^2. Road densities in Roaring Creek would be reduced from 2.54 to 2.1 mi/mi^2. Overall, project area road density would be reduced from 2.7 mi/mi^2 to 2.0 mi/mi^2. Similarly, riparian road densities would be reduced from 2.48 to 2.13 mi/mi^2 in Lower Mad, 3.52 to 2.82 mi/mi^2 in Mills Creek, and from 2.5 to 2.21 mi/mi^2 in Roaring Creek (see Tables 7 and 9).

Hydrologically connected roads would be reduced from 13.3 to 11.3 miles in Lower Mad, from 36.2 to 29.4 miles in Mill Creek, and from 13.9 to 12.1 miles in Roaring Creek. For the project area, total hydrologically connected roads would be reduce by 10.6 miles from 60.6 to 52.8 miles (see Tables 7 and 9).

Miles of roads in areas with intrinsically high erosion potential would be reduced by 8.4 miles from 75.8 miles to 67.4 miles (see Tables 8 and 10). Miles of roads in riparian reserves would be reduced by by 10.1 miles (see Tables 8 and 10). Road stream Crossings would be reduced in all sub-watersheds. Post project there would be 29 fewer road-stream crossings, reduced from 149 to 120 (see Tables 7 and 9). Erosion from decommission and closed road segments and treated crossings is expected to increase immediately following treatment and decrease 1-2 years following treatment (Luce and Black, 2001). Disturbance is expected to be short-term and would be less than if roads were left on the system. Over the long-term, sediment is expected to decrease from current levels as treated crossings stabilize, decommissioned and closed roads re-vegetate and stabilize. A reduction in hydrologic connectivity is expected on the miles of road decommissioned.

Long term stability on decommissioned roads would be improved, culverts would be removed and stream crossings would be stabilized. Decommissioned roads that have been ripped and returned to natural contour would allow for greater infiltration and reduce sheet, rill, and gully erosion. Peak flows near decommissioned roads may decrease as infiltration capacity on adjacent land is increased. Stability would increase on crossings where aquatic organism passage is improved and on roads where culverts are removed or upgraded. Replacing undersized culverts with structures designed to accommodate the 100-year flood would increase stability and reduce plugging and failure potential. Removing undersized culverts and armoring these crossings would also reduce plugging and failure potential.

Some of the effects of roads to watershed function can be mitigated through road design and location (Furniss et al. 1991), implementation of BMPs, and treatments to reduce erosion and hydrologic connection of roads to the stream system. Treatments including road surfacing, improvement of road drainage through construction of waterbars or drainage dips, and seasonal closures to prevent road damage during wet weather can reduce erosion and sedimentation (Burroughs and King 1989, and Bilby et al. 1989). Hydrologic road decommissioning is also an effective method to restore hydrologic function on roads that are no longer needed for access or forest management. While road decommissioning treatments have been found to reduce erosion and sedimentation, the technique does not eliminate all road related sediment delivery to streams (Madej 2001), and erosion and sedimentation may increase in the first two-three years after treatment (Luce et al. 2001). Other road maintenance activities can increase short-term sediment routing to streams through the exposure of additional soil, alteration of slope stability in cut and fill areas, removal of vegetation, and alteration of drainage patterns (Reid and Dunne 1984, Luce and Black 2001).

Effectiveness of road treatments is dependent on type of treatment, erosion rates, and timing and amount of precipitation. While road decommissioning is usually the most effective method to reduce road hydrologic risk, simply closing the entrance to a road does not reduce hydrologic risk. Full hydrologic decommissioning, including removal of culverts, de-compaction of road surface, and return to natural land contour (if needed) are the most effective treatments to reduce road hydrologic risk.

Effectiveness of hydrologic road decommissioning and storm damage risk reduction (SDRR) treatments was evaluated across the Pacific Northwest using GRAIP (Nelson et al. 2012; Cissel et al. 2014). Road decommission was monitored on 68km of road and hydrologic connectivity was reduced by 58%, and sediment delivery was reduced by 64%. SDRR treatments were monitored on 86 km of road and hydrologic connectivity was reduced by 9%, and sediment delivery was reduced by 51%. Post-storm inventories of decommissioned and control roads found that connectivity was reduced by 44% and fine sediment delivery was reduced by 80%. Roads treated through SDRR showed a 67% reduction in fine sediment delivery, but an 11% increase in hydrologic connectivity post storm.

While there are numerous treatments to mitigate the hydrologic effects of roads, not all effects of roads are preventable. A 1983 study in northwestern California showed that 24% of road-related erosion could have been prevented from conventional engineering techniques, with the remaining 76% of erosion caused by site condition and road location (McCushion and Rice 1983). Although this study was only on 344 miles of road, it illustrates the concept that the mere existence of roads increases erosion and sedimentation and supports the practice of full decommissioning of the road prism to minimize risk. GRAIP effectiveness monitoring shows that decommissioning treatments were more effective in reducing sediment delivery and road hydrologic connectivity than SDRR treatments (Nelson et al. 2012).

Stream and Riparian Restoration

Water quality would be improved through treatment of an estimated 3.8 miles of stream channel improvement, and the decommissioning of 10.1 miles (approx. 25 acres) of roads in the riparian reserve.

These treatments would decrease erosion and sedimentation from stream channels and would increase the resiliency of streams to disturbance.

Riparian Function and Channel Morphology

Fuels Reduction Treatment

Fuels reduction treatments on 10,795acres would reduce the potential direct and indirect effects to riparian function and channel morphology if a high severity fire were to occur.

Road and Culvert Treatments

Decommissioning 10.1miles of roads in riparian reserves would improve riparian habitat conditions; increased infiltration capacity on decommissioned roads would encourage vegetation growth. Removing or improving crossings reduces the risk of culvert failure which can remove riparian vegetation and cause instability in riparian reserves. Hydrologic function would be improved on treated crossings because they would no longer be hydrologic barriers during high flows. Hydrologic function would also be improved on treated roads; hydrologically connected road segment length would be reduced and watershed functions affected by roads would be improved.

Stream and Riparian Restoration

Wood would be placed in the channel to mimic natural wood delivery and accumulations in the channel and floodplain. Wood placement can influence channel morphology; logs trap organic matter, and cause deposition of fine sediment. In the short term (1-5 years), wood placement may cause localized areas of erosion and scour to both the stream bed and banks. Lateral scour and channel migration may increase. The longer term effects of wood placement include increasing structure and complexity to the stream system. The wood would stabilize channels and make them more resistant to high flows because there would be greater channel roughness to dissipate energy during high flows. Wood placement would increase pool frequency and quality.

Watershed Condition

The proposed action would improve several attributes and indicators that affect watershed condition as described in Table 10.

Table 10: Description of how the proposed action addresses limiting factors to watershed condition.

ATTRIBUTES /INDICATOR	How the proposed action addresses limiting factors
1.2 Water quality problems	Roads, fuels, and stream restoration treatment would improve water quality (see water quality effects analysis section of this report).
3.1 Habitat Fragmentation	Removal or upgrade of 7 culverts would improve stream habitat connectivity.
3.2 Large Woody Debris	Large woody debris placement in Mad River and Roaring Creek would improve large woody debris numbers and function.
3.3 Channel Shape and Function	Stream restoration treatments in Mad River and Roaring Creek, as well as placement of large woody debris would improve stream channel shape and function. In addition, road treatments would improve hydrologic processes that are altered by the road system that affect flow regimes and geomorphic stream characteristics.
4.1 Aquatic Biota Life Form Presence	Improvement in channel shape and function discussed above would improve habitat and encourage steelhead, bull trout and spring chinook.

4.2 Native Species	See 4.1
5.1 Riparian Vegetation Condition	Improvement of upland function through road treatment would improve the processes that influence riparian vegetation condition. Road decommissioning would improve floodplain connectivity on approximately 25 acres and would improve riparian vegetation condition.
6.1 Open Road Density	Total road density in the sub-watersheds of the project area would range from 2.0 to 2.1 mi/mi^2 once the proposed action is implemented.
6.2 Road and Trail Maintenance	Total road mileage would be reduced and storm damage risk reduction treatments on 90.9 miles of road would increase the resiliency of roads to erosion and sedimentation.
6.3 Proximity to Water	Hydrologically connected roads in the sub-watersheds would range from 11.3 to 29.4 miles once the proposed action is implemented.
6.4 Mass Wasting	Road treatments in areas with mass wasting potential would improve this attribute.
7.1 Soil Productivity	Road decommissioning treatments on 90.9 miles would increase effective ground cover and soil productivity.
8.1 Fire Condition Class	Fuels reduction treatment on 10,795 acres of the project area sub-watersheds would improve fire condition class.
9.1 Forest Cover	This attribute is not expected to be changed through the Mad Roaring Mills project, however fuels treatment would reduce the risk of future stand-replacing fires.
11.1 Extent and rate of spread of terrestrial invasive species	Noxious weed treatments would be completed as part of the proposed action which would slow their extent and spread.
12.1 Insects and Disease	Fuels reduction treatment would improve stand resiliency to insect and disease outbreaks.

Cumulative Effects

Spatial and Temporal Context for Effects Analysis

Similar to analysis of direct and indirect effects, the spatial bound for cumulative effects is the Mad Roaring Mills project area sub-watersheds. Effects are not expected at a scale larger than the project area. The temporal scale for cumulative effects on stream channel function is 30 years, the time it is estimated for watershed improvement projects to improve stream channel function. The temporal scale for cumulative effects on water quality, riparian function, and watershed condition is 10 years, the amount of time it is expected to take for project activities to improve these elements.

Past, Present, and Reasonably Foreseeable Activities Relevant to Cumulative Effects Analysis

Understanding watershed history (i.e., past management activities, hydrologic events, wildfire) is important to build a temporal context of past impacts, current condition and potential future effects. Analysis of watershed history is essential to help predict effects of future management activities on water quality and watershed condition. Ongoing on reasonably foreseeable actions in the project areas sub-watersheds include sheep grazing, road maintenance, snowmobile trail grooming, fire suppression, and invasive weed treatments. Additional projects and conditions that contribute to potential cumulative effects are outlined in the "Cumulative Effects Considerations" document in the project file.

The Mad Roaring Mills project is not expected to change current estimated cumulative watershed effects to water quality, riparian function and channel morphology, and watershed conditions because treatments in the proposed action would improve conditions across the watershed. In addition there is very little land disturbing activity, most of which would take place in isolated locations in the existing road prism.

Localized increases of erosion and sedimentation may occur, however this increase would be short in duration and is not expected to have a cumulative effect at the watershed scale.

Regulatory Framework

Land and Resource Management Plan

The Wenatchee National Forest Land and Resource Management Plan (LRMP) provides standards and guidelines for protection of hydrologic resources. In addition to the Wenatchee LRMP, the Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan provides the framework for protection of aquatic resources. The Fisheries report for the Tillicum project describes how the Tillicum Watershed Restoration meets the ACS.

Federal Law

Clean Water Act

The project is consistent with the Clean Water Act as described in the Management Direction and Existing Condition sections of this report. In addition the Mad Roaring Mills project would improve water quality to ensure the Clean Water Act is met in the future.

Floodplains, Executive Order 11988

Executive Order (EO) 11988 requires the Forest Service to avoid "To the extent possible the long and short term adverse impacts associated with the occupation or modification of floodplains…" The Mad Roaring Mills project would not adversely affect any floodplain and would improve floodplains on select streams within the project area. The project is consistent with EO 11988.

Wetlands, Executive Order 11990

Executive Order (EO) 11990 requires the Forest Service to "Avoid to the extent possible the long and short term adverse impacts associated with the destruction or modification of wetlands". The Mad Roaring Mills project would avoid adverse impacts to wetlands and would improve existing wetland environments. The Mad Roaring Mills project is consistent with EO 11988.

Safe Drinking Water Act Compliance

The 1996 amendments to the Safe Drinking Water Act require federal agencies that manage lands that serve as drinking water sources to protect these source water areas.
Many communities in central Washington rely on water from the Okanogan-Wenatchee National Forest for drinking. The Safe Drinking Water Act (SDWA) is the 1974 federal law that sets standards for drinking water quality. The law requires actions to protect drinking water and its sources, and sets national standards for drinking water to protect against naturally occurring and man-made contaminants (US EPA 2012). A 1996 amendment to the SDWA requires each state to implement Source Water Assessment Programs (SWAP). The SWAP program in Washington is administered by the state Department of Health Office of Drinking Water. There is one State-designated surface water protection area on private land adjacent to the project area and one ground water protection area immediately downstream of the Mad Roaring Mills project. The Mad Roaring Mills project treatments would be downslope of the surface water protection area and would not adversely affect the surface water source. Less than 5 acres of treatment (hand thinning, pile and Rx burn) would occur within the groundwater protection area and would be separated from the well by a large ridge. Consequently, the project would not adversely impact the water system.

Compliance with LRMP and Other Relevant Laws, Regulations, Policies and Plans

The proposed action complies with the Okanogan-Wenatchee Land Management Plan the Aquatic Conservation Strategy of the Northwest Forest Plan, and all relevant laws, regulations, policies including the Clean Water Act, the Safe Drinking Water Act, and Executive Orders 11990 and 11988. In addition, both action alternatives follow direction from the Okanogan-Wenatchee Forest Restoration Strategy, and additional guiding documentation listed in the Management Direction section of this report. The proposed action meets the intent of the Restoration Strategy and other guiding documentation, and would result in greater improvements toward meeting the goals and objectives outlined in these documents.

Degree to Which the Alternatives Address Purpose and Need and Issues

The proposed action meets the purpose and need of the Mad Roaring Mills project as described in the Summary of Environmental Effects section of this report.

Summary of Environmental Effects

This report analyzed potential effects of the no action and the proposed alternatives on water quality, riparian function and channel morphology, and watershed condition. The Mad Roaring Mills project is expected to improve water quality, riparian function and channel morphology, and watershed condition. The proposed action would reduce road density and riparian road density in all of the sub-watersheds. The project would reduce miles of hydrologically connected roads by 10.6 miles, reduce the number of roads in areas with high erosion potential by 8.4 miles, reduce roads in riparian reserves by 10.1 miles, and reduce the number of road-stream crossings by 29. In addition, the proposed action would reduce fire risk on 10,975 acres, improve approximately 25 acres of riparian reserve through road decommissioning, and improve 3.8 miles of stream channels. Through these actions, watershed condition would be improved through a reduction in erosion and sedimentation from the road system, improvement in stream and riparian condition, and through vegetation treatments to reduce the risk of effects to water quality and watershed condition from high severity fires.

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